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# DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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## THREE POTENTIAL WATERPOWER SITES INVESTIGATED NEAR PETERSBURG, ALASKA

Three potentially useful sites for waterpower development near Petersburg, Alaska, have been investigated by scientists and engineers of the Geological Survey according to Secretary of the Interior Douglas McKay.

Field examinations have been made of the geology of dam sites, reservoir sites, and probable diversion tunnel routes for power development along Scenery, Cascade, and Delta Creeks on the mainland in southeastern Alaska. These streams flow westward into Thomas Bay about 20 miles northeast of Petersburg, from points of origin high up on the western slope of the Coast Range. The terrain is very rugged, deeply dissected by river erosion, modified by the great Pleistocene ice sheet, and sculptured by alpine glaciers of Pleistocene and Recent age.

A reconnaissance geologic report has been prepared by John C. Miller and is available in Survey files for public inspection. It describes the physical characteristics of the area that relate to power development, paying particular attention to evaluation of potential dam sites at the outlets of Scenery, Swan, and Ruth Lakes. The geologic feasibility of these sites is one of the determining factors in evaluating the waterpower potential of the streams on which the natural lakes are located. Also described are geologic conditions along probable tunnel routes for conveying water stored in the lakes to powerhouse sites at or near tidewater. The three reservoirs behind the proposed dam sites are in relatively impervious rock and no structural or other geologic conditions were observed which might cause appreciable leakage. Rock fill or concrete dams, gravity or arch type, could be constructed at all sites.

Copies of the report which is entitled, "Geology of Waterpower Sites on Scenery Creek, Cascade Creek, and Delta Creek near Petersburg, Alaska," are available for public inspection at the following offices of the Geological Survey: Library, 1033 General Services Administration Bldg., Washington, D. C.; in California at 4 Homewood Place, Menlo Park, 724 Appraisers Bldg., San Francisco, and 529 Post Office and Court House, Los Angeles; 244 Federal Bldg., Tacoma, Washington; and in Alaska at 117 Federal Bldg., Juneau, 210 Glover Bldg., Anchorage, Wright Bldg., Palmer, and Brooks Memorial Mines Bldg. at College. It is also available at the Territorial Department of Mines, Juneau, Alaska.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

# GEOLOGY OF WATERPOWER SITES ON SCENERY CREEK, CASCADE CREEK, AND DELTA CREEK NEAR PETERSBURG, ALASKA

By
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September 1955



OPEN FILE

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## ABSTRACT

Dam sites were examined at the outlets of Scenery Lake, Swan Lake, and Ruth Lake which are located on Scenery Creek, Cascade Creek, and Delta Creek, respectively. The Scenery Lake dam site is partly in quartz diorite and partly in hornblende plagioclase gneiss. The Swan Lake and Ruth Lake dam sites are in quartz diorite. The bedrock at these dam sites is suitable for the height of dams that would be required to achieve the full development of the potential power of the streams. No appreciable leakage from the reservoirs is anticipated.

Tentative tunnel routes for conveying the water from the lakes to powerhouse sites at or near tidewater were examined. The tunnel routes from Scenery Lake and Swan Lake would be in quartz diorite. The tunnel route from Ruth Lake would pass through quartz diorite and diorite gneiss.

The geologic examinations described in this report indicate that the development of the potential power of the streams under consideration is feasible as far as geologic conditions are concerned.

# INTRODUCTION

## Purpose and Scope

This reconnaissance geologic report was made to evaluate the geologic feasibility of the sites for the various structures that would be required for the development of hydroelectric power from Scenery Lake, Swan Lake, and Ruth Lake. These lakes are on Scenery Creek, Cascade Creek, and Delta Creek, respectively. The field examinations included the dam sites at the outlets of the three lakes and tentative tunnel routes from these lakes to powerhouse sites at or near tidewater. The geologic feasibility of the sites under consideration is one of the determining factors in evaluating the water-power potential of these streams. A report on the water-power resources of these streams is in course of preparation and will serve as a basis for the classification of the public lands with respect to their water-power values. The field work on which this report is based was carried on during July and August 1951. For examination of the reservoir, dam and tunnel sites, a total of 29 days was spent on the Scenery Lake and Scenery Creek areas; 21 days on the Swan Lake and Cascade Creek areas; and one day on the Ruth Lake and Delta Creek areas. The author was assisted by J. L. Colbert, hydraulic engineer, who had worked in the area the previous season obtaining the control data for a compilation of a topographic map.

## Maps and Photographs

A map entitled, "Plan and Profile, Cascade Creek and vicinity, Alaska, Dam Sites," published by the U. S. Geological Survey, plate 1 in this report, served as a base map for the geologic mapping. This map (in pocket) extends from Scenery Lake on the north to the Patterson River on the south and inland 4 to 5 miles from the east shore of Thomas Bay. The map is on a scale of 1:24,000 with a 40-foot contour interval. Included on the same sheet are detailed maps of the Scenery Lake dam sites, scale 1:4,800; and Swan Lake dam site, scale 1:2,400; both with 10-foot contour intervals. Underwater contours are shown on Scenery Lake, Swan Lake, and Ruth Lake. Profiles are shown for Scenery Creek, Cascade Creek, and Delta Creek.

Aerial photographs, taken in 1948, are available for this area and were used in the field work.

## Acknowledgments

Acknowledgment is due to the Alaska Communication System for their friendly cooperation and assistance in maintaining radio communications with the field party.

The author also expresses his appreciation to J. L. Colbert, hydraulic engineer, and to D. K. Fowler, field assistant, for their assistance in the field work.

## GEOGRAPHY

### Location

The area investigated is on the mainland, about 20 miles northeast of Petersburg, Alaska, on the east side of Thomas Bay, an arm of Frederick Sound, and is approximately 100 miles southeast of Juneau, Alaska. Scenery Creek, Cascade Creek, and Delta Creek flow westward into Thomas Bay, being effluents of Scenery, Swan, and Ruth Lakes. These locations are shown on the index map of the Thomas Bay area (figure 1) which is a copy of a portion of plate 1 of Survey Bulletin 800. The Scenery Creek site has been described briefly by F. F. Lawrence on page 5 of an open file release, July 6, 1950, entitled, "Waterpower Resources of Scenery Creek near Petersburg, Alaska."

### Climate and Vegetation

The climate is characterized by moderate temperature the year round, including mild winters and cool summers, and by heavy precipitation. The mean annual precipitation at Petersburg for the 15 years 1927, 1931-1932 and 1938-1949 was 111 inches. However, the mean annual runoff at the Cascade Creek gaging station for the 14 years 1918-1928 and 1947-1949 was 149 inches. Although the records do not cover exactly the same periods, they indicate that precipitation in the area of study is greater than at Petersburg.

The area is within Tongass National Forest and, except

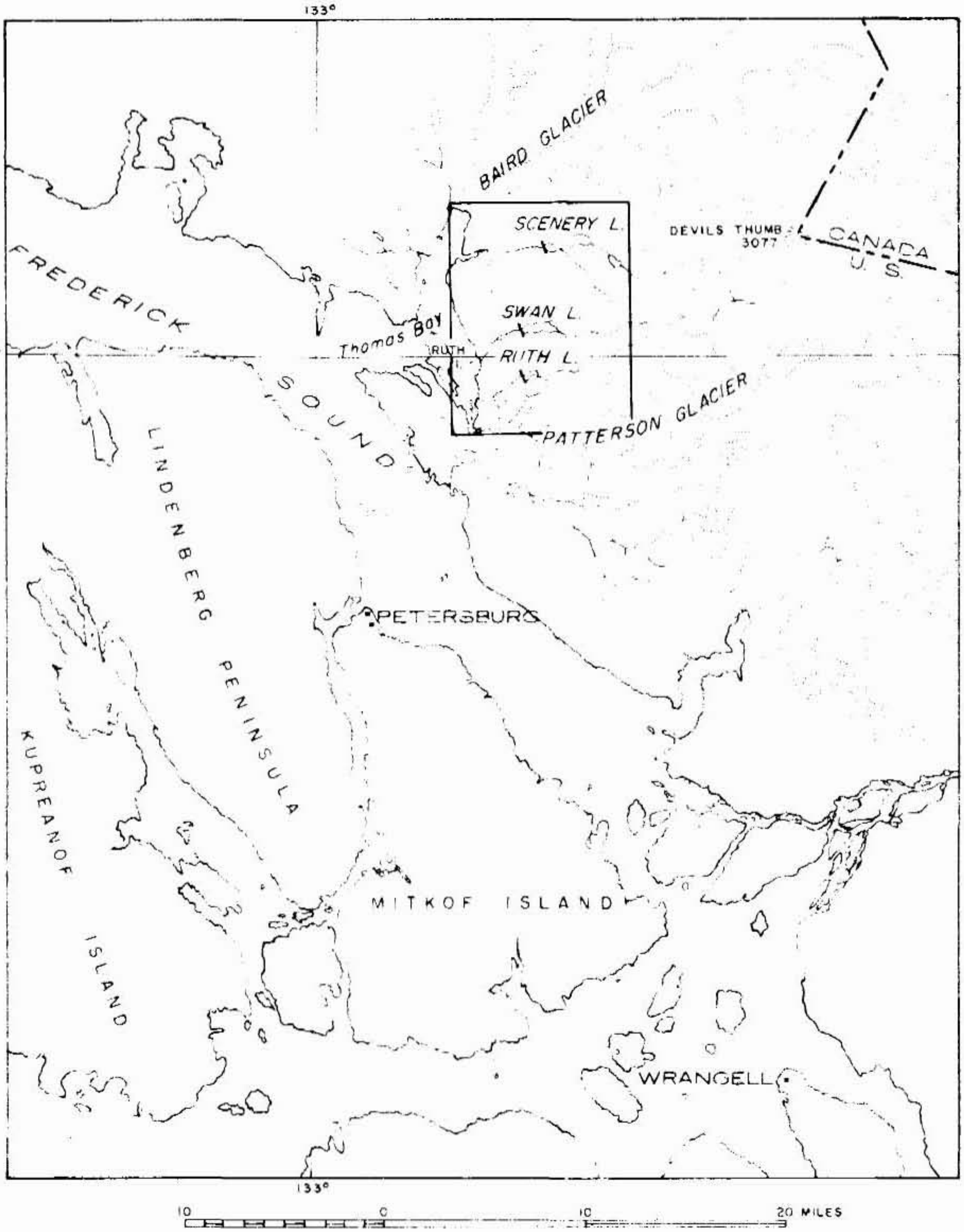


Figure 1. Index map, showing location of dam sites near Petersburg, Alaska

the steep slopes, is covered with a dense growth of timber consisting of western hemlock, Sitka spruce, western red cedar, and Alaska cedar. From sea level to about 2,000 feet the forests have a dense undergrowth of bushes, mainly salmonberry and huckleberry, and other vegetation, including devil's club. In certain slide areas willow and alder form an almost impassable barrier. The best timber is in the well-drained areas on the steep hillsides, but there is a large quantity of poorer grade timber suitable for paper pulp within the drainage areas of the three creeks and the area bordering Thomas Bay.

## Accessibility

The three dam sites investigated are at the outlets of Scenery, Swan and Ruth Lakes. Scenery Lake is 3 miles east of the coast and 957 feet above sea level. Swan Lake is about 2½ miles from the coast and 1,514 feet above sea level. Ruth Lake is less than 2 miles east of the coast and 1,353 feet above sea level. A development at tidewater on Scenery Cove would be accessible to ocean-going tugs and large vessels, as soundings in the cove at mean lower low water, recorded by the Coast and Geodetic Survey on map no. 8210 of Thomas, Farragut and Portage Bays, range from 9 to 21 fathoms. A powerhouse for a dam on Swan Lake, if built on Cascade Creek near sea level, would be accessible from Thomas Bay. There are no roads in the area under consideration and any road construction would be complicated by the extremely rugged terrain and the consequent occurrence of rock or snow slides. The trail up Cascade Creek is well marked to Falls Lake. It is discontinued at the lake and it is necessary to use a boat to travel the length of the lake. The trail from Falls Lake to Swan Lake is indefinite and quite steep, having been obscured in places by snowslides. The Forest Service maintains a skiff on Scenery and Swan Lakes, but none is available on Ruth Lake.

## PHYSIOGRAPHY

The rugged mountainous character of the area involved provides excellent topographic locations for the three dam sites examined. In the higher altitudes valley glaciers and waterfalls descend from the ice cap and this melt water forms streams entering the lakes. The western slope of the Coast Range has been "... deeply dissected by river erosion, modified by the great Pleistocene ice sheet, and sculptured by alpine glaciers of Pleistocene and Recent age." (Buddington and Chapin, 1929, Survey Bull. 800, p. 23). The maximum height of the surface of the Pleistocene ice was probably less than 5,000 feet, as evidenced by the sharp ridges and lack of roundness above altitudes of 4,200 to 4,500 feet. Locally, valley glaciation in Recent and Wisconsin time has resulted in alpine sculpture, but probably the most pronounced glacial erosion was due to the Cordilleran glacier complex in Wisconsin time.

Evidence of the great ice flood of Pleistocene time is found in the fiords such as Scenery Cove, in the three lake valleys, in the occurrence of hanging valleys such as the creek valley on the south side of Scenery Lake and about 1.2 miles from the head of the lake, a similar valley at the head of drainage southeast of Swan Lake, and others in the region under consideration.

At the mouths of the hanging valleys on the south side of Scenery Lake and southeast of Swan Lake are low, rounded, transverse ridges which may be designated "lips" roughly spanning the valley, except at the streams flowing through the post-glacial notches. The origin of this residual form at the entrance of these hanging valleys arouses some speculation, but it may be similar to that of a "threshold" in the outer or downstream part of a long, gently sloping rock basin near a piedmont plain in that the principal cause was the slower movement, hence less erosive capacity, of the valley glacier at this point. It seems probable, however, that factors other than spreading or debouchment, and probably excess of ablation over supply, may have been important contributing agents in their formation. It may be postulated that slower erosive capacity was due to (1) the overriding of the upper ice on the debris-laden ice at the base of the tributary valley glacier, or (2) the slower movement due to the resistance at the junction of the ice in the main valley glacier to the entrance of the tributary glacier of the same elevation. The walls of the valley of Scenery Creek are grooved and striated, as are the walls of the fiord named Scenery Cove.

On the rock walls of Scenery Cove some of the larger grooves caused by glacial action are roughly parallel and slope downward toward the east at an angle of about $5^{\circ}$. The inclination may be due to imbrication of ice in the old valley glacier in its course to the sea. There are many cirques in various stages of preservation. The U-shaped tributary valleys contain lateral, medial, and end moraines of pre-existing alpine glaciers. The three lakes investigated were developed by glacial action which produced deep trough-like basins gouged out of the rock. The rather sharp knife-edged or comb ridges between these glacial lakes are the result of frost wedging, of extensive alpine glaciation, and, to some degree, of difference in character of the rock, that is, the occurrence of gneisses within the diorite mass.

In the main creek valleys the cross section is not a simple "U" and the valleys are not always broad and flat. They occasionally show evidence of successively narrower valleys produced by more than one period of erosion. The loosely consolidated material left by glaciation in the valleys has been modified by normal stream erosion, and gorges have been cut in the rock floor of the valley. The streams emanating from the lakes follow tortuous and precipitous paths to tidewater, rapids and falls being numerous. The falls on Cascade Creek at the head of Falls Lake are between 60 and 70 feet high. Similar falls were observed near the head of the broad, flat valley of the stream which enters the northeast side of Swan Lake.

These falls were probably formed as rock steps produced by the quarrying action of a glacier. The steep walls of the three main creeks are intersected by glacial troughs or by deeply incised valleys of tributary creeks. Most of the topographic features described must be considered when any conduit is planned from the lakes to power plants near tidewater.

## GENERAL GEOLOGY

The limits of the mapping by Buddington and Chapin extend about 3 miles east of the bay, but plate 1 of Survey Bulletin 800 does not include Scenery Lake and its catchment area. Swan Lake and Ruth Lake are near the edge of the area previously mapped, but part of their catchment basins are beyond the area mapped by Buddington and Chapin.

Plate 2 is a geologic map resulting from previous work and this reconnaissance. Occasional samples of rock at the dam sites, tunnel routes, and reservoir areas were taken for petrographic examination, but only samples of each of the dam sites were examined in thin section. The engineering geology of each site will be discussed following the description of the geology of the area as a whole.

### Igneous Rocks

The predominant rocks of the mainland of southeastern Alaska and of the area involved are quartz diorite of the composite Coast Range batholith and gneisses and schists of the metamorphic-complex belt lying adjacent to the batholith. The quartz diorite intrusive is reported by Buddington and Chapin (Bull. 800, p. 61) to be more or less contaminated with inclusions, remnants, or assimilation products resulting from the breaking up or disintegration of schist. In the area under consideration the intrusive sheets of quartz diorite appear to contain very few assimilation products, particularly along the valley of Scenery Creek. Some increase in the mafic mineral content, mainly hornblende, was observed along Cascade Creek, and a marked increase was evident along Delta Creek farther south. This rock will be referred to in this report and illustrations as diorite.

Dikes of aplite or felsite are more common in the Swan Lake basin than in the Scenery Lake basin. These vary in width from a few inches to tens of feet.

The texture of the diorite varies from fine to coarse and the fabric is equigranular, although at times it has a slightly porphyritic appearance. From north to south across the area an increase in the content of ferromagnesian minerals in the diorite was observed and locally, at least, the country rock resembles gabbro. The quartz diorite which comprises the western portion of the Coast Range batholith has a width of 3 to 15 miles in southeastern Alaska and is considered to be of Upper Jurassic or Lower Cretaceous age.

## Metamorphic Rocks

The metamorphic rocks are crystalline schists and injection gneisses, and the main belt of these rocks has a width of 13 miles in the Thomas Bay region, roughly paralleling on the southwest the Coast Range batholith. Occasionally the diorite exhibits linear flow structure and hornblende is oriented or roughly parallel, giving it a more or less gneissic appearance. This type of structure in the intrusives is more prevalent in the southern part of the area. The gneisses are predominantly hornblende plagioclase gneiss, but mica and garnet occur in some of the gneisses. These gneisses and schists in general show various stages of injection and occur as blocks, stringers, or as infolded masses occasionally with intercalated beds of limestone or marble in places as much as 10 feet thick. These gneisses and schists, however, may be regarded as members or integral parts of the larger and more common occurrences of hornblende gneisses.

In a number of localities it was difficult to determine the boundary between diorite and gneiss because the exposures vary from feebly metamorphosed diorite gneiss to highly metamorphosed hornblende plagioclase gneiss and garnetiferous mica schist. This was the case on the northeastern side of Swan Lake where the limits of the metamorphic rock are in doubt, in part due to forest cover and topographic relief. The boundary shown between diorite and gneiss is to be regarded as more or less indefinite, but it delimits the area of predominantly metamorphic rocks which, however, may not be of the same age or origin in different parts of the area mapped. In the explanation on the map (plate 2) the rocks are classified broadly under four types of interest to construction engineers. The age of these metamorphic rocks is probably Ordovician to Jurassic or later.

## Unconsolidated Rocks

In the broader valleys and in the valleys entering Thomas Bay glacial boulders and gravels occur. The valleys of the streams entering Swan and Scenery Lakes contain deposits of sands in limited amounts. The streams have carried glacial debris toward Thomas Bay, although a large portion of the deposits in these valleys must have been left by recession of the valley glaciers of Quaternary age. The glacial debris has been reworked locally and Recent stream deposits consist of a large amount of reworked morainal material. Some forested areas in the broader valleys entering Thomas Bay are underlain by outwash from glaciers which occupied the area. Pro-glacial streams from the broad lobe of Baird Glacier deposit a large volume of sand and gravel which has been added to morainal material left by recession of the glacier and by glacial streams in the past. These streams carrying rock flour and silt muddy the waters of Thomas Bay for a distance of several miles.

## Structure

The dam sites investigated are near the western edge of one of the major geologic features of southeastern Alaska, that is, the Coast Range batholith of the mainland. The Kuiu anticlinorium is 50 miles or more west of the mainland, and between this anticlinorium and the mainland lies the Juneau synclinorium (Buddington and Chapin, 1929, Survey Bull. 800, pl. 22), striking northwestward roughly parallel to other major structural elements. The beds in the Juneau synclinorium are overturned to the southwest. On the mainland, however, in the area between Delta Creek and Scenery Creek the strike of the foliation, which is generally north to northwest parallel to the western border of the Coast Range batholith, is locally interrupted by beds of gneiss or schist cutting across the regional strike. The structures observed are probably residual from sediments existing prior to intrusion of the magma.

Numerous shear zones are found within the area under discussion, but any appreciable displacement which might have occurred is masked by forest growth and rock slides. Jointing is commonly steep, 75° to vertical, usually in a northeast and a northwest direction, rather widely spaced, and usually cuts across the lineation. Among the numerous structural patterns in evidence on the aerial photographs, a well-defined line appears extending from a point near "Boulder" and "Land" as shown on the topographic map of the area (plate 1), to a point about 2 miles eastward near the headwaters of South Fork Scenery Creek. A most pronounced system of joints or fractures observed on aerial photographs extend in a northwest-southeast direction parallel to the Juneau synclinorium. This lineation is intersected by another one trending in a northeast-southwest direction. A number of linears are shown on plate 2 which were located by George Plafker of the Engineering Geology Branch, Geologic Division, Geological Survey, by examination of aerial photographs. Overturned isoclinal folds in the gneiss occur sporadically, but, in general, the structure near the western margin of the batholith is not complex. A number of main divides or sharp ridges consist of gneiss. Whether their occurrence is due to the tectonics of the region, resistance to erosion, or to glaciation was not determined.

## Seismic Activity

According to a Seismic Probability Map of the United States, September 1950, by the Coast and Geodetic Survey, these dam sites are on the east edge of what is designated as Zone 2, an area in which structures are reported to have been moderately damaged one or two times. The adjoining Zone 1 to the east is a region of minor damage by earthquakes but no structural change. In the explanatory note by the Coast and Geodetic Survey accompanying the map cited it is stated that: "A compilation of records shows that between 70 and

80 per cent of earthquakes occur in the same general regions, although not necessarily at the same epicenters, where previous earthquakes have occurred and that these regions are generally within fairly well-defined zones or belts. ... At present there are not sufficient data available to prepare a general seismic probability map of the country based on surface geology. The zone limits shown on this map are based almost entirely on earthquake history and represent the general combined opinions of a number of scientists." In view of the geographic locations of the dam sites, only minor to moderate damage might result from an earthquake, according to available information.

## ENGINEERING GEOLOGY

### Water Power Development Possibilities

The general plans or methods by which power would be developed in this area are described in a report on the water-power resources of this area now in preparation by J. L. Colbert. In general, power development will require the creation of storage to equalize the pronounced irregularities in stream flow, and to convey the water by tunnel and penstock from the storage sites to powerhouse sites at or near tidewater. Opportunity for storage exists in three lakes, viz., Scenery Lake on Scenery Creek, Swan Lake on Cascade Creek, and Ruth Lake on Delta Creek. Storage development could be accomplished on Scenery Lake and Swan Lake by the construction, in each instance, of a dam at the lake outlet to raise the lake surface above its natural level, or by drawing the lake below its natural level, or by a combination of the two methods. Ruth Lake is comparatively shallow and has a small capacity below lake level so any storage development would require the construction of a dam at the lake outlet. In order to utilize the full potential head the powerhouse sites would be as near tidewater as practicable and, in general, would be near the mouths of the creeks under consideration. It would also be possible to convey the water from Swan Lake to a powerhouse site at the mouth of Scenery Creek, thus using the water from both Scenery Lake and Swan Lake in a single powerhouse. The field examinations were directed to the dam sites at the lake outlets and the suitability of the lakes as reservoir sites, to tunnel routes from each of the three lakes to a point near the creek mouths and from Swan Lake to a powerhouse site near the mouth of Scenery Creek. Only tunnels were considered as a means of conveying the water from the storage sites to the head of the penstocks leading to the powerhouse sites. In view of terrain conditions as well as climatic conditions, the use of canals or pipe lines was considered impractical. The water surface elevation in the reservoirs may vary from 100 to 150 feet. Consequently, any tunnels considered will have to withstand the hydraulic pressure equivalent to the maximum range in the elevation of the reservoir surface.

The tunnel courses considered in this report are shown on plate 2. These courses were selected to insure an adequate cover of rock over the tunnel at all points. For simplicity of illustration, the tunnel courses have been shown as straight lines but in actual construction any sharp angles would of course be avoided. Sections along the tunnel routes are shown on plates 3, 4 and 5 and indicate the probable geologic conditions that would be encountered. For illustrative purposes the tunnels from Scenery Lake and Swan Lake have been shown as heading slightly below present lake levels. The actual elevation of these tunnels may be as much as 150 feet lower, depending on method of storage development in these lakes. The tunnel sections have been drawn showing the penstock underground in order to give an indication of the conditions that would be encountered if this plan were adopted rather than the more common practice of having the penstock on the surface. The sections are intended to show the geologic conditions, as near as they can be inferred from present information, that would be encountered by a tunnel.

The character of the rock beneath the surface is more or less inferred on the basis of field investigation and samples obtained on or near these tunnel courses and because the dioritic intrusions are recognized as part of the Coast Range batholith. The rock to be penetrated is competent to maintain the tunnel openings and to withstand the hydraulic pressures expected. The surface profiles along the tunnel courses were drawn from the topographic map. The locations of the penstocks were determined by inspection of the topography, and their courses were selected to provide a minimum cover of 100 feet.

The engineering geology of each dam and tunnel site discussed in the following pages is the result of reconnaissance work in these areas. More detailed examination, aided by drill holes, will be necessary prior to the planning of any construction. The three reservoirs behind the proposed dam sites are in relatively impervious rock, and no structural or other geologic conditions were observed which might cause appreciable leakage from the reservoirs. Rock fill or concrete dams, gravity or arch type, could be constructed at all sites.

## Scenery Lake power site

### Topography

The catchment basin above Scenery Lake, which receives the melt from two valley glaciers terminating near the lake shown on plate 1 about one and a half miles east of Scenery Lake has steep walls carved by former glaciers. Scenery Lake is a glacial lake and its steeper slopes are barren of vegetation, but the rock slides and alluvial fans at the foot of some of the slopes are usually covered with alder and brush. The floor of the valley above Scenery Lake has a minor amount of relief, is in part tree-covered and in part covered by alder and brush. Some spots are poorly drained, and swamps caused by beaver dams or by snow slides damming up drainage courses with rock and debris are common.

The valley bottom of Scenery Creek for the first mile upstream from the head of Scenery Cove is about $\frac{1}{2}$ mile wide and of relatively low relief. Fallen timber and large blocks of rock are common near the edges and on the adjoining slopes.

## Geology

### Rock types

The basin of Scenery Lake has been gouged out of solid rock, almost entirely quartz diorite. The basin walls both above and below the lake outlet were sampled at intervals of about $\frac{1}{4}$ mile in order to discover any changes in the wall or country rock that might be obscured by forest growth. Occasional samples were also taken at intervals in the upper valley of Scenery Creek as far as the lake and about $1\frac{1}{2}$ miles eastward. Changes in the content of the ferromagnesian minerals, principally hornblende, were noted in a few localities where the diorite became gneissic.

At the outlet of the lake a contact between hornblende plagioclase gneiss on the southwest and quartz diorite on the northeast crosses the dam site area diagonally, as shown on plate 2. Both the diorite and the gneiss are firm rocks which do not weather deeply and possess low porosity. The jointing in the diorite is approximately vertical, rhomboidal, and widely spaced. Individual layers of gneiss are as much as 2 to 4 feet in thickness. About 200 feet downstream from the lake outlet in the canyon wall on the right bank the ferromagnesian minerals in the gneiss appear to increase, probably due to a segregation. However, this was not examined closely because it was difficult to reach. The lake outlet is a V-notch caused by plucking of gneiss. Aplitic dikes and sills are common in the diorite.

Structure

Evidence of geologic structure is provided by the occurrence of infolded crystalline schist or gneiss which has been included as bands, blocks, and stringers in the quartz diorite. The foliation or the separate layers dip northward at 57° and strike about N. 60° W. at the dam site. Although it was not followed for the entire length of the outcrop, the gneiss zone apparently extends in the line of strike northwestward to a point about 1,000 to 1,500 feet north of Scenery Creek and about one mile northwest of the outlet of Scenery Lake. It is not known whether the gneiss was completely assimilated in the diorite northwest of this point.

A well-defined shear or fault zone appears on the aerial photographs beginning at a point 2.7 miles north of the mouth of Cascade Creek on Thomas Bay extending more than 2 miles in an easterly direction. In the absence of good exposures the direction of movement was not determined, but the trace of this zone on the aerial photographs indicates a southward dip of the plane of fracture. As this line of weakness does not extend through the Scenery Lake dam or reservoir sites and probably becomes nonexistent east of the South Fork Scenery Creek, it was not traced beyond this point. A tunnel from Swan Lake to Scenery Creek, however, would cross this zone about 2 miles south of the point where South Fork flows into Scenery Creek. In addition to this shear zone, a number of linears are shown on plate 2 which were located by examination of aerial photographs.

Dam Sites

In this report two possible dam sites below the outlet of Scenery Lake are considered. These are shown on plate 3 as A-A' and B-C-D-E-F. The water power report indicates that a dam slightly over 90 feet in height (above the lake surface) would be required if this site was used for developing storage.

The first site, A-A', is located about 50 feet downstream from the actual lake outlet and the geology at this site is shown in plan and in section on plate 3. The left abutment and the section across the channel would be in a hornblende plagioclase gneiss. The remainder of the section and the right abutment would be in a hornblende quartz diorite. The gneiss forms a natural weir through which the lake waters flow; consequently, no water-borne deposits exist at that point.

The slopes of both abutments are stable. On the right or north wall the abutment would be in the nearly vertical wall of diorite which rises toward a knoll about 200 feet above the lake. This slope presents no serious slide problem. The slope of the abutment on the south side, however, is largely bare gneiss with a minor amount of brush and timber, particularly in the upper slopes. The slope is as much as 60° over short distances but averages about 45° over most of the slope, and rock loosened by ice and frost action could slide toward the dam. Snow building up on the upper slopes of this hill could slide toward this abutment, carrying rock and timber with it.

A dam at the first site would have a crest length of about 900 feet and a maximum height of about 130 feet above the channel. The bedrock at this site is suitable for a flexible fill type or masonry type of dam of the height required.

The second site considered is designated as B-C-D-E-F on plate 3. A section along this line is shown on plate 3. This will require a main dam, E-F, across the channel and an auxiliary dam, B-C, across the saddle to the north. The main dam, E-F, would be located about 300 feet downstream from the lake outlet. This site would be entirely in the metamorphic rock or hornblende plagioclase gneiss, the individual layers of which range in thickness from 2 to 4 feet and in general dip northward at an angle of 57° N., with a strike of N. 60° W. This foliation persists between the site and the lake outlet and beyond probably several miles to the southeast. This crystalline gneiss appears to offer a satisfactory foundation for a dam of the height considered, although probably as much as 10 feet of rock might have to be scaled from the steep high wall on the south side of Scenery Creek to reach firm rock for the abutment in that bank. It is doubtful whether any grouting between layers of gneiss would be required. This dam would be about 140 feet in height above the stream channel and would have a crest length of slightly less than 300 feet. The main dam, E-F, would not be subject to slides on the right bank, but the left bank would be subject to the same slide conditions described for site A-A'.

The auxiliary dam, B-C, plate 3, mentioned in the preceding paragraph, is located about 900 feet west of the lake outlet across the saddle on the north bank. A dam at this site would have approximately the left one-third of its length and the south abutment in gneiss and the right two-thirds of its length and the north abutment in quartz diorite. It would have a height of about 35 feet above present ground level and a crest length of about 250 feet. Foundation and abutment conditions are satisfactory for any type of dam that might be selected for this site.

The area between the main dam in the channel and the auxiliary dam in the saddle, represented by the line C-D-E, plate 3, is well above the maximum assumed flow line of 1,050 feet and is all in plagioclase gneiss. This barrier is relatively impervious and would serve as a natural dam. The area between B and C is covered with brush, timber, and muskeg. The slope at the south abutment, C, is gentle and no slide problems would be experienced. The slope at the north abutment of the auxiliary dam, however, consists of massive quartz diorite boulders which may be the remnants of a lateral moraine of the valley glacier or they may have moved down from higher elevations north of these cliffs by normal erosion processes.

Whether the dam is the overflow or the nonoverflow type, erosion of the channel of Scenery Creek by waters from the spillway or spillway apron would be a minimum as the gneisses in the area are firmly crystallized and probably sufficiently resistant to dissipate the effects of hydraulic friction and cavitation.

Reservoir

The reservoir is almost entirely in hornblende quartz diorite with a minor area of hornblende plagioclase gneiss exposed near the dam site. Both types of rock are relatively impermeable, and in the absence of pronounced faulting or continuous openings which might provide channels for escape of waters impounded by the dam, no appreciable leakage from the reservoir is anticipated.

The steep slopes on the borders of the lake show evidence of snow slides at a number of points. The principal creeks entering the north and the south sides of Scenery Lake thread through debris cones, and during flood stages carry some detrital material to the lake. A negligible amount of silt may be carried into the lake, but it is clear at all times. However, this debris is more or less stable, and even if rock slides occur they would constitute no serious impediment in the reservoir.

Timber and brush cover the swampy area drained by the upper part of Scenery Creek at the east end of the lake, but some of the steep to nearly vertical slopes around the lake support no timber. The dam site area north of the creek, however, is timber-covered. The greatest amount of timber elsewhere is 75 to 100 feet or more above the lake at present.

Tunnel

A tunnel for conveying water from Scenery Lake to a powerhouse at or near the head of Scenery Cove could be located on either side of the Scenery Creek valley. The field investigations were directed primarily toward a south bank location but the valley walls on the north side of the creek were also examined at intervals. With the exception of the occurrence of plagioclase gneiss, the wall rock on the north side was essentially the same as on the south side of the Scenery Creek valley.

For illustrative purposes in this report a tunnel route was assumed on the south side of the valley, shown in plan as A-B-C-D on plate 2 and in section on plate 3. As shown on plate 3 the tunnel diverts from the lake at the 900-foot elevation. In actual development this may vary from as low as the 800-foot elevation to as high as the 950-foot elevation. The geologic conditions as near as can be inferred from the available information are essentially the same within this range in elevation. The tunnel alignment, as shown on plate 2, is based on an assumed elevation of 900 feet at the diversion from the lake and an adequate cover of rock, approximately 100 feet, where the alignment crosses the several creek valleys.

As shown on plate 2, a tunnel route on the south side of the valley would have a total length of nearly 20,000 feet and would be in hornblende plagioclase gneiss for about the first 1,200 to 2,000 feet from the lake and would otherwise be in quartz diorite throughout. A location on the north side of the valley would be in quartz diorite for approximately the first half mile from the lake, then pass through a zone of hornblende plagioclase gneiss for 1,500 to 2,000 feet with the entire remaining portion in quartz diorite.

The character of the rock to be penetrated, whether on the south or north bank, assures stability in tunnel openings throughout most of its length. However, one or more zones of weakness appear on the aerial photographs along the proposed tunnel route near the South Fork Scenery Creek and these zones should be drilled prior to location of the tunnel or the penstock. No other unfavorable geologic conditions are believed to exist along the tunnel routes that would most likely be considered from Scenery Lake to Scenery Cove.

Construction Materials

Either rock fill or concrete type dams could be built at the sites considered. Ample amounts of large boulders and blocks occur in slide areas, in the creek valley, or adjacent to the steep walls of the main valleys. The largest proportion of these boulders is quartz diorite containing variable amounts of hornblende, a minor proportion consists of mica schist and hornblende gneiss. The South Fork Scenery Creek contributes, in addition, boulders of white marble or crystalline limestone. On the north side of Scenery Creek the valley is largely underlain by glacial debris and there are occasional gravel bars in the creek, particularly near mile 1.0. However, an inexhaustible supply of relatively clean, fine to coarse sand, also gravel, exists at the north end of Thomas Bay where the broad outwash plain from Baird Glacier is within reach of boats of shallow draft. This deposit is about 1½ miles north of the entrance to Scenery Cove. Other minor deposits of sand and gravel were observed in the valley of Scenery Creek above the lake and in creeks entering the lake.

## Swan Lake power site

### Topography

The north and the south boundaries of the Cascade Creek drainage basin are marked by comb ridges. The catchment basin above Swan Lake is characterized by evidence of glacial action both past and present. Streams descending from valley glaciers and from the ice cap flow into the lake. The cirques or minor basins which contribute their drainage to the lake directly are probably the work of alpine glaciers. The creek which enters the northeast portion of the lake is fed by the melt of the ice cap and two valley glaciers several miles east of the lake. This creek flows through a broad relatively flat valley about a mile long, at the upper end of which is a falls that descends about 60 feet to the valley floor.

Cascade Creek which flows out of Swan Lake descends about 350 feet in the first half mile. A falls at the head of Falls Lake is about 80 feet high. After leaving Falls Lake through a narrow gorge the stream gradient is steeper, and in the next mile the creek follows a straight course and descends about 850 feet. In the last half mile to the coast it falls about 250 feet and flows through a narrow, rock-walled valley. The step-like character of the upper stream bed is shown on the profile of Cascade Creek on the topographic map (plate 1). As its name implies, there are many rapids and cascades throughout the length of Cascade Creek.

The side slopes of the lake in general are not quite as precipitous as those of Scenery Lake and are covered in a large part by forest growth.

## Geology

### Rock types

The reservoir rock in general is gneissic in character, particularly on the south side of the lake, and, in comparison with the Scenery Lake area, exhibits a definite increase in content of mafic minerals. There may be two sheets of intruded batholithic material in this area, one of which crosses the outlet of the lake. One of these intrusive sheets may be classed locally as a gabbro, the other as hornblende quartz diorite. These rocks have not been mapped separately and in detail because they are part of the same batholithic intrusion in which quartz diorite predominates, and a great deal more time would be required to map each accurately.

The massive gneiss layers on the south side of the lake consist of hornblende and plagioclase with quartz, garnet, biotite, and epidote as accessory minerals. The hornblende crystals are parallel to the foliation. Aplitic dikes 6 inches to 3 or 4 feet in thickness were observed, although southeast of the lake the aplitic zone may be very much thicker but is probably of lenticular shape. Small light-colored dikes are numerous and conspicuous around the lake and they intersect each other at various angles. Beds of marble or crystalline limestone varying from a few inches to 4 or 5 feet in thickness were observed in the gneiss north of the lake outlet, also southeast of the lake, and between this point and the falls on the creek which enters the lake on the northeast side. The marble is pure white and is occasionally medium to coarsely crystalline, but some thin stringers are pure calcite.

Deposits of glacial sand and boulders occur in the valleys of the creeks on the east end of the lake. Angular boulders and reworked glacial debris occur at the mouths of drainage channels at or near lake level. Cascade Creek below the gorge at the outlet of Swan Lake flows through cobbles and boulders before dropping over the falls at the head of Falls Lake.

Around Falls Lake the country rock is hornblende quartz diorite and the ledge which forms the falls is also hornblende quartz diorite. Sampling at intervals along Cascade Creek to the coast revealed no abrupt change in the composition of the bedrock, although the content of hornblende appears to increase westward and the rock becomes definitely gneissic in character.

Structure

Near the east end of the lake the strike of the layers of hornblende plagioclase gneiss in a small exposure is N. 55° W., dip 47° toward the northeast. At the contact with the hornblende quartz diorite near the west end of the lake the gneiss contact trends northwest-southeast. However, along the creek entering the northwest side of the lake near the lake outlet and about 500 feet higher than the lake calcareous gneiss is exposed in a small sharp, isoclinal fold about 75 feet across. This calcareous gneiss zone extends over the divide beyond the headwaters of the South Fork Scenery Creek and trends slightly west of north. There appears to be a shear zone on both sides of Swan Lake following roughly the creeks entering the lake near the outlet. The creek on the south side of Swan Lake east of the lake outlet, however, follows more or less the contact of the hornblende plagioclase gneiss and the quartz diorite. In the lower part of the South Fork Scenery Creek the calcareous gneiss was absent but was observed approximately a mile above the main creek.

The slightly incised valleys near each abutment site and transverse to the axis of the proposed dam, between 800 and 1,000 feet to the north and the south of the lake outlet, so far as could be determined by field examination, are not faults but probably are joint fractures which eroded more easily than the neighboring rock. These localities should be drilled to verify this supposition because it was not possible to inspect closely these points by reason of forest growth.

The straight course of Cascade Creek southwestward from Falls Lake, as shown on the map, for a distance of about 4,000 feet, its abrupt turn at that point southeast for about 1,000 feet and another right-angle turn southwestward toward the coast is evidently the result of the structural pattern of the area. This might affect the stability of a tunnel from Swan Lake to a point near the mouth of Cascade Creek.

Dam Site

The narrow gorge immediately downstream from the outlet of Swan Lake presents favorable opportunities topographically for the selection of a dam site. The bedrock in this gorge consists entirely of hornblende quartz diorite. The south or left wall of the gorge is practically bare for more than 100 feet above the elevation of Swan Lake. The north or right side of the gorge is covered with thick brush, trees, and large boulders and blocks of diorite. Within the narrower portion of the gorge large blocks of diorite, 10 to 20 feet in maximum dimension, line the stream channel and to a lesser extent form the outlet of the lower portion of the channel. There are two small incised valleys, one on either side of the gorge, roughly parallel to Cascade Creek and several hundred feet higher than the elevation of Swan Lake. Examination of these localities furnished no evidence of faulting, either active or dormant, and it was concluded that jointing was solely responsible for these incised valleys. Exploratory drilling to verify this should be included as part of any detailed investigation of this site.

The right or north side of the gorge, in view of the cover of trees and brush along with the large irregular boulders, should be reasonably free from slides. The left or south wall might be susceptible to slides, however, being practically bare and somewhat steeper.

The most likely location for a dam would be at the narrowest part of the gorge which is about 500 feet downstream from the lake outlet. This is shown both in plan and section, A-A', on plate 4. A dam at this site would have a crest length of 290 feet. The waterpower report shows that a dam that would raise the lake level approximately 100 feet would be required at this site to attain the desired regulation of the outflow from the lake. The foundation and abutment conditions are satisfactory for the construction of either a masonry or rock-fill type of dam of the height indicated. The rock conditions in the channel downstream from the dam would effectively withstand the erosion from any spillway discharge.

Reservoir

The reservoir rock includes a large amount of hornblende gneiss, diorite gneiss, and calcareous gneiss containing beds of marble and, in addition, hornblende quartz diorite. With the exception of the gneiss containing marble, near the west end of the lake, none of the rocks observed would cause any leakage of consequence from the reservoir. The location of these calcareous gneisses near the lake would not promote leakage, and permeability is lacking in the other rocks in the reservoir. No faults, joints, or openings were observed that might cause water losses. However, the two notches on each side of the lake outlet previously described should be core-drilled.

The reservoir rock supports a good growth of timber over much of the lake basin and, with the exception of a few areas subject to snow slides, the slopes can be considered stable.

An increase in elevation of the lake surface would flood many timbered areas. The valleys of the two creeks entering the upper portion of the lake are covered with alder and brush.

Tunnels

Water from Swan Lake could be diverted to a powerhouse site at or near the head of Scenery Cove or to a site at or near the mouth of Cascade Creek. The routes or courses for these two tunnels are designated on plate 2 as G-F-E-D and H-I-J-K, respectively. Sections along these routes are shown on plate 4. In these figures the tunnels have been shown as diverting at lake level. If the storage was developed by drawing the lake below its natural level these tunnels would be about 125 feet lower than indicated. From the information available conditions would be essentially the same whichever elevation is considered.

Swan Lake-Scenery Cove tunnel

The tunnel route from Swan Lake to Scenery Cove, G-F-E-D, as considered in this report, would follow a course parallel to the creek entering the northwest end of the lake and the South Fork Scenery Creek. (See plate 2.) Reconnaissance of these creek valleys discloses that gneiss containing white marble or crystalline limestone bands and stringers is continuously exposed from a point about 150 to 200 feet above Swan Lake to the divide between Scenery Creek and Swan Lake drainage. Although detailed information is lacking, this gneiss zone apparently is continuous in a northerly direction beneath the snow and ice cap to a point on South Fork Scenery Creek about $1\frac{1}{2}$ miles below the divide. Whether these infolded or included blocks and stringers of gneiss exist at the depth below the surface to the probable tunnel grade, that is, below an elevation of 1,500 or possibly 1,375 feet is not known, but this can be determined by diamond drilling.

The reconnaissance along this tunnel route discloses that the first sizable outcrop of marble occurs about 600 feet above lake level at an elevation of about 2,100 feet. Based solely on this observation, it would appear that a tunnel grade at an elevation of 1,500 feet or lower would not encounter the calcareous gneiss, particularly if the tunnel were driven west of the outlet of Swan Lake and South Fork Scenery Creek through the quartz diorite along a course approximately that indicated by the line on plate 2. This tunnel would intersect a shear zone, which apparently extends eastward from the bay to a point about 1½ miles south of Scenery Creek, as shown on plate 2. In addition to this zone, six linears are shown which may indicate fracture zones that could affect tunneling operations along the route indicated.

The total length of this tunnel would be about 3½ miles, and the length of the penstock or pressure tunnel would be about 2,500 feet.

Cascade Creek tunnel

The tunnel route from Swan Lake to a powerhouse site at or near the mouth of Cascade Creek for consideration in this report was selected on the north side of the Cascade Creek valley, and is designated as H-I-J-K on plate 2. The alignment indicated was based on topographic considerations so that there would be an adequate rock cover over the tunnel at all points. A course on the south side of the valley was not considered as desirable by reason of several reentrants resulting from Recent and Pleistocene erosion and glaciation. Sampling at intervals between the lake and the bay along Cascade Creek showed that the tunnel route as indicated would be in hornblende quartz diorite throughout its entire length. Four shear zones may be intersected by the proposed tunnel. A section along the route is shown on plate 4. The tunnel would be about $2\frac{1}{4}$ miles in length. If the powerhouse site was at the mouth of Cascade Creek a penstock over 4,000 feet long would be required. If a satisfactory powerhouse site could be had at a point along the shore about 3,500 feet north from the mouth of Cascade Creek the penstock length could be reduced to about 2,000 feet or less.

Construction Materials

There are ample supplies of large boulders, principally quartz diorite, near the outlet of Swan Lake and on the southeast end of the lake in the creek valley that are suitable for the construction of a rock-fill or concrete type of dam. Some sand and gravel may be obtained in this valley, but the largest supply is in the valley between the falls and the point where the creek enters the northeast side of the lake. If the quality and quantity of this sand and gravel are unsatisfactory both may be obtained from the outwash plain of Baird Glacier on Thomas Bay.

## Ruth Lake power site

Topography

The north wall of Ruth Lake is nearly vertical, but the south wall is less steep and covered with trees. The channel out of the lake is apparently 2 to 5 feet deep, probably due in part to the accumulation of boulders, after which Delta Creek enters a narrower channel. The north bank, less than 200 feet from the outlet, is almost vertical to a height of 60 to 70 feet above stream level, but the south bank slopes more gently, and large blocks of quartz diorite have accumulated below the outcrop of bedrock about 50 feet above the stream. Delta Creek follows a more circuitous course than Scenery Creek or Cascade Creek to sea level in a distance slightly in excess of 2 miles.

## Geology

### Rock types

The exposed north wall of the lake contains numerous dikes that have penetrated the diorite in the same manner as at Scenery and Swan Lakes to the north forming a similar reservoir of smaller dimensions. The joints in the intrusive masses also govern minor drainage to some extent. Samples were taken on the north and the south banks. The lower 50 feet of the north wall was identified as hornblendite and apparently is a segregation, but the quantity of hornblende diminishes in the upper part of this wall and the rock seems to change to a gabbro. Farther downstream the right bank is hornblende quartz diorite. The south bank is essentially the same type of rock where exposed. In general, the bedrock along Delta Creek toward the bay contains increasing amounts of ferromagnesian minerals and is gneissic in a number of localities. Within ½ to 3/4 mile of Thomas Bay the bedrock is entirely hornblende gneiss.

### Structure

The foliation of the schist and massive gneiss within a half mile of the coast dips generally eastward, although these may be overturned beds of the Juneau synclinorium. In the gneiss zone near the coast dips as high as 70° eastward were noted. The foliation becomes less distinct eastward and the bedrock is essentially a part of the diorite mass. In the absence of a boat, little opportunity was afforded to examine the structure of the reservoir, but so far as could be determined from the outlet of the lake and from aerial photographs no faulting or folding has affected the reservoir area, at least no unfavorable conditions were apparent. The reservoir area appears to be a part of the main mass of hornblende quartz diorite.

Dam Site

The Ruth Lake dam site shown on plate 5 was not surveyed but is an enlargement of that portion of the topographic map, "Plan and profile Cascade Creek and vicinity, Alaska, dam sites."

Delta Creek, immediately downstream from Ruth Lake, flows through a very narrow canyon section about 600 feet in length. About 200 feet downstream from the lake outlet the right or north bank is very steep with the first 60 to 70 feet above the stream practically vertical. The left or south bank is also very steep but not quite as steep as the north bank. The bedrock through the canyon section above mentioned consists mainly of hornblende quartz diorite although there is an increase in mafic mineral content as compared with the area examined along Cascade Creek and Scenery Creek to the north. The slopes on both sides of the canyon, at the most probable site for a dam, appear to be stable.

The waterpower studies indicate that it would be necessary to raise the level of Ruth Lake as much as 215 feet to obtain the desired regulation of the outflow. The required dam would be about 245 feet high and have a crest length of 400 feet. The rock conditions in the canyon are satisfactory for the construction of either a masonry or rock-fill dam. Rock conditions in the channel downstream from the dam location would withstand the erosion from spillway discharges.

Reservoir

The country rock at the lake outlet is hornblende quartz diorite; locally, however, it approaches the composition of a gabbro. From the brief observation made and by examination of aerial photographs, it is concluded that the entire reservoir is this type of rock. No faults or continuous openings which might permit escape of impounded water were observed, and the lack of permeability of the bedrock indicates that the probability of any appreciable leakage from the reservoir is remote. A small area of unconsolidated sediments is present in the stream valley at the upper end of the lake.

The slopes of the reservoir appear to be stable throughout, although minor snow and rock slides might occur on the north side of the lake from the bare slopes and in the stream valleys.

The north wall is steep to vertical for a height of over

500 feet above the lake and supports little timber. The south border of the lake supports a good growth of timber.

Tunnels

Plans for the utilization of the water from Ruth Lake might require diversion by tunnel along one of three different routes, viz., (1) from Ruth Lake to a point at or near the mouth of Delta Creek; (2) from Ruth Lake to a point at or near the mouth of Cascade Creek; and (3) from Ruth Lake southwestward to some point in the Patterson River valley. The first two are designated as L-M-N-O and P-Q-K on plate 2. The third route is not shown.

The quartz diorite rock in the Delta Creek valley, based on observations along the foot trail, is locally gneissic in character and becomes entirely gneiss as the coast is approached, that is, toward the west. A tunnel from Ruth Lake to the mouth of Delta Creek would be mainly in the quartz diorite, except ½ to 3/4 mile from the coast where it would be in gneiss.

Rock conditions along the route to Cascade Creek were observed only in the vicinity of Ruth Lake and the mouth of Cascade Creek. The rock in both of these areas was quartz diorite and it is believed that the entire route would be in the quartz diorite.

No observations were made in the Patterson River valley but based on aerial photographs it is believed that a tunnel route from Ruth Lake terminating in this valley would encounter essentially the same rock conditions as were observed at Ruth Lake, viz., quartz diorite and gneiss.

Construction Materials

The large blocks and boulders of hornblende quartz diorite near the outlet of the lake would contribute some material for construction of a rock-fill dam, but quarrying may be necessary. If concrete is to be used in construction of a core or a facing, it may be possible to obtain a limited amount of sand and gravel at the upper end of the lake. It was not possible at the time of this investigation to examine this locality. If this source is inadequate it may be necessary to obtain concrete aggregate in the Patterson River delta or at the head of Thomas Bay.

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